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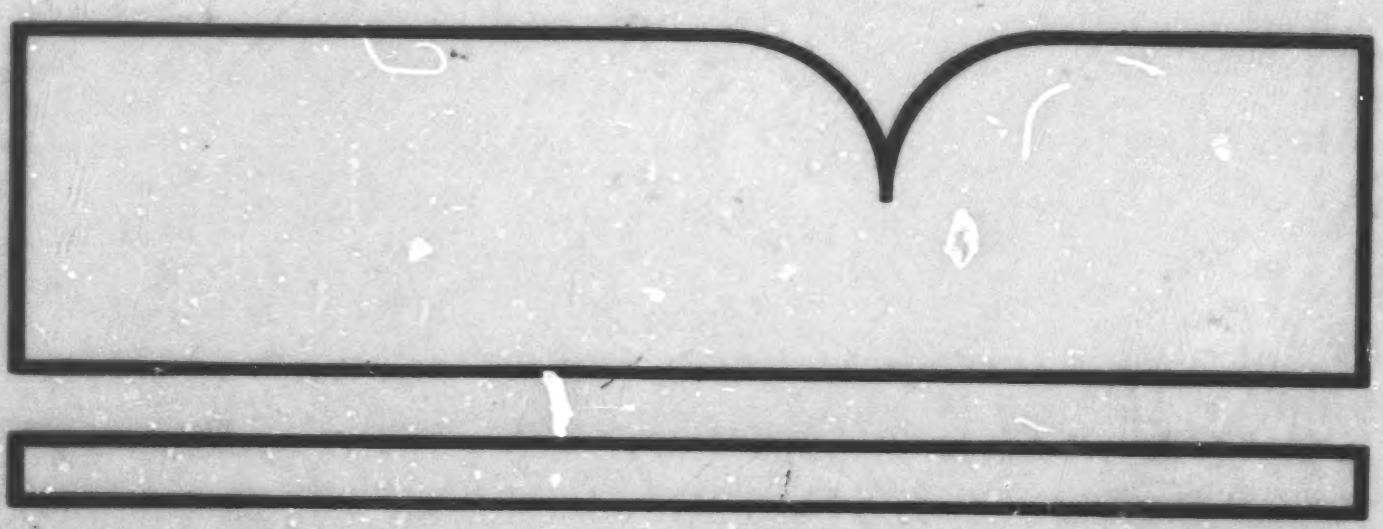

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Overview of Epidemiologic Studies on the Association of Hard and Soft Water with Cardiovascular Disease

Gunther F. Craun
U.S. Environmental Protection Agency
Cincinnati, Ohio

HEALTH EFFECTS RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

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16. ABSTRACT

Recent epidemiologic studies associating hard and soft water with cardiovascular disease are reviewed. in the report.

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Welcome to this morning's session on the epidemiologic association of hard and soft water with cardiovascular disease. There has been a change in this morning's agenda. I had planned to present data on the occurrence of inorganic contaminants in drinking water as an introduction to Dr. Sharrett's presentation. Dr. Sharrett was scheduled to discuss the results of a cooperative epidemiologic study conducted in 1974-75 by the National Heart, Lung, and Blood Institute, the National Center for Health Statistics, and the Environmental Protection Agency to investigate the association of some 28 bulk and trace elements in tap water and several measures of cardiovascular disease assessed during physical examinations of 4200 adults in 35 geographic areas of the United States. Instead, he will focus on the copper and zinc concentrations determined in this particular study, and I will add to the comments made by Lee McCabe yesterday on the status of research in this area since the 1979 conference.

In the past five years several excellent reviews have been published on water hardness and cardiovascular disease (Folsom and Prineas, 1982; Masironi and Shaper, 1981; Comstock, 1980; NRC, 1980; Comstock, 1979; Sharrett, 1979; NRC, 1979). More than 40 publications discussing the relationship between drinking water quality and cardiovascular disease have been published since Kobayashi (1957) first reported a statistical correlation between cerebrovascular disease mortality and the acidity of water supplies in Japan some 27 years ago. Most of the associations of drinking water and cardiovascular disease have been obtained from statistical-correlational studies of mortality rates in areas having different water characteristics. In general, the studies have shown a negative association between cardiovascular disease mortality and water hardness, that is, lower cardiovascular mortality is found in areas where the hardness of drinking water is high. This association is presently considered statistical rather than causal. Although biologically plausible in some respects, the epidemiologic evidence is not specific; individual exposure and possible confounding by individual risk indicators have not been considered, the data are inconsistent, and the associations are relatively weak. In addition, hardness and total dissolved solids have also been found to be negatively associated with numerous other causes of death, including total mortality, cancer mortality, sudden death from other than arteriosclerotic heart disease, cirrhosis, and peptic ulcer and positively associated with fatal accidents, congenital malformations, and chronic obstructive pulmonary disease. The negative association of water hardness with cardiovascular mortality was reported in most, but not all, studies involving large areas. However, there have been numerous failures to find similar negative associations within small geographic areas and in comparisons of communities. It is possible that the correlation of water quality with cardiovascular mortality is actually measuring the correlation of some other geographically related factor such as demographic, socio-economic, and cultural characteristics. Some studies have adjusted for factors such as altitude, climate, latitude, humidity, air temperature, and socio-economic status and found that they have influenced the correlation of water quality with cardiovascular mortality.

Since I have not been active in this research area as long as Lee McCabe, I can not say that I have become as discouraged as he has with our inability at this time to draw definitive conclusions on the resolution of the so-called "water factor" and cardiovascular disease. Rather, I have become encouraged of late. Not that I think we'll necessarily be able to provide people like Joe Cotruvo and Peter Toft with all the information they might need for developing regulations, but because I see a logical progression of epidemiologic studies from the descriptive and statistical-correlational studies to the more recent epidemiologic studies where investigators have attempted to quantitate the possible effects, estimate individual exposures to specific water constituents, and assess some of the likely confounding and modifying factors.

In the past, few studies provided an estimate of the possible effect of a water factor. In the United Kingdom cardiovascular mortality is about 40% higher in extreme soft water areas compared to hard water and in the United States this figure is about 15%, and it has been suggested that this might be the "maximum effect" of a water factor in these countries. More recently Neri (1974, 1975) estimated that the "maximum effect" of a water factor might be 20% in Canada, and Comstock (1971; NRC, 1979) calculated the relative risks due to soft water - 1.25 for total cardiovascular mortality for white males aged 45-64 in the United States and 1.19 in England and Wales. Using multiple regression techniques to assess the association of hardness and standardized mortality ratios while controlling for climate and socio-economic factors, Shaper, Packham, and Pocock (1980) reported that preliminary results of the British Regional Heart Study indicate an effect on the order of 3-4% increase in cardiovascular mortality for every 100 mg/L decrease in total hardness. Perhaps Dr. Pocock will comment further on this during his presentation. At the American Medical Association's Symposium on Drinking Water and Health in 1983, Dr. Sharrett (1984) discussed a similar analysis conducted for 484 cities in the United States which indicated when soft water cities were compared with hard water cities in the same region and the results adjusted for demographic variables the mortality rates were approximately 5% higher. I hope Dr. Sharrett will discuss this further during his presentation.

In addition to the two negative studies mentioned by Lee McCabe, I also found two publications in the 1983 literature describing studies on water quality and cardiovascular disease. I do not intend to provide a detailed critical review of these studies, but my general observation is that the results from these studies are inconclusive. The studies are small case-control studies and are basically pilot studies. In Italy, Lanzola, et al. (1983), studied the diets of 99 families: thirty-three families which were considered cases because one family member had experienced a death due to coronary heart disease and 66 population control families matched on age, family size, and occupation. No difference was found between case and control families in total mineral intake for calcium, magnesium, zinc, lead, and cadmium from samples of drinking water collected in spring and winter and food from a 1-week market basket survey. In Finland Luoma, et al. (1983), assessed the association be-

tween calcium, magnesium, and fluoride and acute myocardial infarction. Cases were males (30-64 years of age) who had been discharged with a first acute myocardial infaction from Kotka Central Hospital. Both a population control and a hospital control (surgical patients) matched for age and type of community with cases were selected for comparison. Analysis of 50 case-hospital controls pairs and 50 case-population control pairs indicated no association with calcium, but an association between low fluoride ($\leq$0.1 ppm) and low magnesium ($\leq$1.2 ppm) and acute myocardial infarction was reported. The relative risk for acute myocardial infarction in cases compared to population controls was 4.67 (95% confidence interval 1.30, 25.32) for low magnesium and 4.40 (95% confidence interval 1.62, 14.87) for low fluoride. The 95% confidence intervals, however, were quite large indicating the reported rates are unstable.

My final comment concerns the evaluation of exposure in these studies. Gillies and Paulin (1983) showed there was more than a ten-fold variation in the amount of water people drink daily and noted that the only reliable way to determine mineral intakes from water is to analyze representative samples of water actually consumed. The lack of a precise estimate for exposure to various minerals in water may have influenced the results of epidemiologic studies conducted in this area, and the use of total hardness as exposure variable is considered questionable. It is important to accurately assess exposure not only to increase the sensitivity of epidemiologic analysis but also to assist in the possible development of regulations.

It has been suggested that trace metals leached from water piping by soft or corrosive water may be responsible for increased cardiovascular mortality. If this is the case, at least in the United States, we have the option of revising the drinking water standard for each metal or reducing the concentration of various metals by making the drinking water less corrosive to plumbing materials. Calcium and magnesium are likely possibilities as beneficial constituents in hard water. High calcium concentrations in hard water may reduce or prevent the absorption of low levels of metals such as lead or cadmium. Another possibility is that hard water is a source of an essential element that is deficient in the diet. For example, the magnesium content of hard water might be sufficient to prevent a deficiency where dietary magnesium is marginal. If this is shown to be the case, we might be able to recommend to water utilities some modification in the lime softening process which would precipate calcium but not precipate magnesium. This is theoretically possible because of the excess lime requirements to form $Mg(OH)_2$ precipate and the need to raise the pH to 10.5 for maximum precipitation of $Mg(OH)_3$ while the maximum precipitation of $CaCO_3$ occurs at pH 9.5. While in theory this may be possible, I invite the engineers in the audience to comment with the understanding that this is a hypothetical example only.

In conclusion, the epidemiologic studies conducted to date, while suggestive of an association between hard water and decreased cardiovascular mortality or between soft water and increased cardiovascular mortality, have not provided sufficient evidence to support recommenda-

tions that municipal waters not be artifically softened by lime or ion exchange although it is clear that softening by ion exchange at the municipal water plant or individual home will increase the sodium concentration of drinking water. The increased sodium concentrations could adversely affect those on low sodium diets. Additional research is needed before recommendations can be made regarding the advisability of removing calcium or magnesium from drinking water. There are benefits associated with reducing the corrositivity of drinking water and preventing the leaching of metals from plumbing materials, but it is not clear at this time whether this will also result in decreased cardiovascular mortality.

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